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M42/M46 GRENADE BODY MANUFACTURING PROCESS

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18. SUPPLEMENTARY NOTES

This project was accomplished as part of the U.S. Army's Manufacturing Methods and Technology Program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in the production of Army materiel.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M42/M46 grenade
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This project was initiated to develop an alternate, less costly manufacturing process for the M42/M46 grenade metal parts. Several different manufacturing processes were independently investigated resulting in the conclusion that the warm backward extrusion process produced an equivalent grenade body while offering a significant reduction in cost.

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SUMMARY

The M42/M46 grenade is a high production item used as a submunition in the M483A1 and M509 projectiles. The present manufacturing process was developed concurrently with the grenade development. At the time, it was the only process available that was capable of producing a grenade body meeting the specification requirements.

There have been several improvements in manufacturing techniques over the years; therefore, a program was initiated to investigate other, less costly, manufacturing procedures for producing the M42/M46 grenade body.

Several different processes were independently investigated and the results showed that a grenade body manufactured by a warm backward extrusion process offered the best results while producing an estimated cost saving of $0.09 per body.*

The extruded M46 was equal or superior to the original M46 in all categories. The extruded M42, which met or surpassed all the grenade requirements except for lethality, demonstrated less lethality than the original M42.

The recommendations of this report are to modify the M46 Technical Data Package to allow the use of the warm backward extrusion process, and to continue to investigate various fragmentation patterns for the purpose of increasing the lethality of the extruded M42.

* Costs throughout the report were computed in 1985.

FOREWORD

The following restrictions were imposed on the development of the manufacturing process for the M42/M46 grenade:

1. No changes to the grenade body dimensions.

2. No degradation of the grenade functioning and performance characteristics.

3. Application of specifications MIL-G-50546 and MIL-G-48047 in their entirety.

4. No changes in the functioning and performance characteristics of the M483A1 projectile.

5. No degradation of the safety characteristics of the grenade and projectile.

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INTRODUCTION

The M42/M46 grenade body is manufactured from strip stock material using drawing and machining operations. This manufacturing process, the only economical method available at the time the grenades were developed, permits a high production rate while maintaining the dimension and physical requirements in the Technical Data Package.

Although the process has been highly successful for several years, it does have some shortcomings. Material waste is high. Approximatley 40% of the steel purchased for production ends up as waste, to be sold as scrap. The M42 grenade has a fragmentation pattern on the interior surface which is embossed on the material prior to the drawing operations. The embossing creates stress risers during the forming operations which cause internal cracks.

Since there have been improvements in manufacturing technology since the grenades were first introduced, a project was initiated to investigate the new technology and develop an alternate manufacturing process which would decrease the formation of internal cracks and reduce costs.

DISCUSSION

The M42/M46 grenade body is manufactured from 4140 or boron steel strip material. A typical process flow chart is shown in figure 1. A disk approximately 4 inches in diameter is cut from the strip and put through a series of draw operations to form the basic grenade shape. A restrike operation forms the shoulder, then trim and machining operations complete the body. A two-phase program was initiated to provide the information needed to determine the best alternative to this process.

In the first phase, four separate contracts were awarded for independent investigation of four different manufacturing processes. Each contractor developed his own process, including tooling and other special requirements, and was required to deliver 100 each M42 and M46 grenade body assemblies to the Government for tests and evaluation.

The four contractors and their respective proposals were:

1. AVCO. Two-piece design. The body was to be fabricated from 4140 seamless tubing, the cap was to be drawn from 4130 sheet steel, and the two parts were to be joined by laser welding. A knurling tool was to be developed for applying the M42 fragmentation pattern.

2. Dayron. Two-piece design. For the M42, the tube section was to be made from embossed 4140 steel coil formed and welded in a tube mill. For the M46, 4140 seamless tubing was to be used. The cap for both the M42 and M46 was to be drawn from embossed 4140 steel coil. The tubes and caps were to be joined by copper brazing.

3. Tracor-MBA Associates. Two-piece design. A 4140 steel rod was to be cut into slugs, then warm backward extruded into cups. The open portion of the cup was to be flared into a cone shape. The pattern was then to be pressed into the cone portion and the cone returned to a cylindrical shape by pushing through a closing die. The closed end of the cup was to be punched out and warm forged into a cap configuration, then copper brazed to the cylinder.

4. Gulf & Western. One-piece design. Hot rolled 4140 steel rod was to be annealed, sheared into slugs, heated, and warm backward extruded into the grenade shape. A warm strike pattern was to be developed for the M42 fragmentation pattern.

All of the proposed processes used the same trim and machining operations as the original process to finish the body assemblies.

Since three of the four contractors proposed a two-piece design, an additional requirement was added to the body assembly: The cap-to-body joint had to withstand a 15,000-lb force without failure.

All of the proposed processes would require modifications to the existing M42/M46 grenade production facilities, as shown in table 1.

RESULTS

Phase 1

All of the contractors encountered difficulty during the Phase 1 development and, in the end, parts with deviations were submitted for evaluation, since time and funding constraints prevented replacement or rework of the samples and the dimensional deviations would have little effect on the evaluation.

The Gulf & Western Corporation encountered difficulty in producing a grenade body with a full shoulder. A warm strike operation was developed to move material into the shoulder area and fill the corner. This operation was unsuccessful in producing a square corner. All the contract funds were expended on several modifications to the process in an attempt to produce parts with square corners, and additional funds were required for completion of the contract. The contract was terminated due to lack of progress.

The grenades delivered by AVCO showed indications of ovality at the open end and weld spatter on the interiors. The M42 grenades met the transverse and longitudinal requirements of the M46; however, the proposed M46 failed to meet the cap push-out requirement of 15,000 lb. Seven of 20 stud pull tests were below the 500-lb minimum requirement. AVCO used a machined rather than the originally proposed drawn cap.

Dayron Corporation were convinced that their proposed two-piece M42 grenade body would meet the crush requirements for the M46. Therefore, they delivered 200 M42's and proposed a cost saving by eliminating the need for the M46 in the projectile. The grenades exhibited some minor dishing discrepancies on the cap top, and the internal diameter was oversized across the embossment and undersized at the open end. The grenades failed to meet the M46 longitudinal crush requirement by almost 1,000 lb, and the transverse crush tests were significantly below the M46 requirement. The cap push-out force averaged 9,332 lb, which was below the required 15,000-lb minimum. The mode of failure was the flat part of the cap fracturing from the side walls. The stud pull values were within the specification.

The Tracor-MBA parts showed out-of-tolerance conditions on several dimensions. The largest inner diameter was undersized, the datum locations were out of tolerance, and the cylinder sides were not parallel. There was also evidence of excessive copper brazing material. The magnetic particle inspection for cracks rejected 10 samples for cracks in the major outside diameter and in the cap. The M42 samples failed both the longitudinal and transverse crush requirement. Three samples out of 37 tested failed to meet the 15,000-lb standard for cap push out. The stud pull test was not performed because the parts did not fit into the fixture.

The remaining parts from all of the manufacturers were shipped to Lone Star Army Ammunition Plant (LSAAP) for loading and penetration tests.

The AVCO and Tracor-MBA grenades successfully passed the penetration test requirements. A fragmentation test was also performed, and both contractors' grenades were satisfactory.

The sidewall on several Dayron grenades split during the loading operation and all further work was suspended. Examination of the parts revealed that the split did not occur at the weld. The sidewall was somewhat thin.

Evaluation of the Phase 1 results (tables 2 and 3) revealed that no one process demonstrated a clear superiority over the others. Specifically, the following conclusions were drawn:

1. The integrity of the two-piece design was questionable.

2. The adequacy of the welded tubing was questionable.

3. All processes (i.e., parts) exhibited shortcomings.

4. MBA's patterning technique could cause incipient cracking.

5. AVCO's process was the simplest and the price approached current price.

6. Dayron's process was the closest to the existing process (except for the tube mill).

7. MBA's process (warm backward extrusion) showed the most potential for cost savings.

Therefore, it was decided that development work would continue on two processes in Phase 2 of the program.

Phase 2

Since one of the processes for which work was to continue in Phase 2 was a two-piece design, a requirement to develop an inspection procedure for the cap-to-body joint was also included.

Two contracts were awarded for independent investigation of the two processes.

Dayron Corporation was tasked to investigate the two-piece body, and Tracor-MBA, the warm backward extrusion process. A parallel investigation of the two processes was conducted until each manufacturer delivered 200 grenade bodies for evaluation.

In the Dayron process (fig. 2) embossed flat stock was formed into a tube and the seam welded. A second flat strip was used to form the dome by the drawing process. The dome was then copper brazed to the tube to form the grenade body (fig. 3). This process was identical to the first proposal under Phase 1.

The first attempt to manufacture the two-piece body was unsuccessful. The ID requirements of the grenade drawing could not be met. The first sample was purchased on waiver. When the bodies were loaded at the loading facility, the grenades failed along the sidewall. The bodies split open in the loading press and LSAAP refused to load the remaining bodies. Dayron Corporation assured the government that these problems could be corrected. A second contract was awarded to Dayron to continue development of the two-piece body.

The sidewall problem was corrected, but the problem of the undersized internal diameters continued. Dayron never was able to solve the dimension problems and parts were again delivered on waiver. Dayron eventually admitted that the internal diameter requirements would never be met and a drawing change was requested.

A second problem that resulted from the two-piece body configuration was the inspection of the copper brazed joint. An inspection process was developed that would discover a hole that extended completely through the joint; however, the worst case was considered to be a void in the joint that does not extend completely through. Powder could be entrapped in the void and when the projectile was fired, setback forces could cause the dome to move, pinching the powder and causing a malfunction. No inspection process was ever developed to discover a void in the copper brazed joint.

Because of the previously discussed dimensional and inspection problems, and the promising development of the one-piece extruded body, the Dayron two-piece body development program was terminated.

The Tracor-MBA one piece, warm backward extruded grenade was a parallel development program to the Dayron Program. Because the extruded grenade body demonstrated more promise for success, it was chosen as the "best" alternate process for production of the M42/M46 grenade body.

The Tracor-MBA warm backward extrusion process was changed from its initially proposed two-piece design. Tracor-MBA was tasked to continue development of what essentially was the Gulf & Western one-piece design, and to incorporate the AVCO-developed knurling process for the fragmentation pattern.

A flow chart of the Tracor-MBA warm backward extrusion process is shown in figure 4, and the extrusion station configurations are shown in figure 5.

It was proposed that hot rolled rod material be annealed, sheared into slugs, preheated, and warm backward extruded. Then the currently used restrike operation would be used to form the shoulder (fig. 6). All of the currently used machining operations would be used to finish the grenade body.

The contractor delivered finished M42/M46 grenade body assemblies to the government for further testing.

TESTING

Tracor-MBA demonstrated that an extruded grenade body could be produced meeting all the dimensional and strength requirements. The government had to demonstrate that it would meet performance and safety requirements. The following tests were conducted:

1. Static penetration with modified stand-off
2. Fragmentation
3. Lethality
4. M483A1 projectile ballistics (inert and HE)

The static penetration with modified stand-off was performed at LSAAP in accordance with the lot acceptance criteria requirements of M42/M46 grenade Specifications MIL-G-50975B and MIL-G-48062B. The extruded grenades were loaded on the normal LSAAP M42/M46 load line and no special procedures were used. The load line was interrupted and the extruded grenades were placed on the line. In order to assure continuity, a sample of the standard loaded grenades was selected just prior to and after the extruded grenades were loaded. The standard loaded grenades were used as the control.

The specification requirement for the modified standoff test is that the body loading assembly penetrate a minimum of 5.5 inches of mild steel. If two or more assemblies fail to penetrate the 5.5 inches, the grenade lot is rejected. The sample size is 30 body loading assemblies.

The standard grenades that were used as a control sample all successfully penetrated the 5.5-inch steel plate with no failures. The M46 extruded grenade sample also penetrated the 5.5-inch steel plate with no failures. The M42 extruded grenade sample had one failure of 5.25 inches; however, this was within the requirement for lot acceptance.

A second lot of each M42 and M46 extruded grenade bodies was delivered to LSAAP. These lots were also loaded and a sample selected for the modified penetration tests. Each sample had one failure. The extruded M42 failure only penetrated to a depth of 3.75 inches and the extruded M46 failure penetrated to a depth of 4.8125 inches. Both of the lots from which the samples were taken were accepted, since the specification requirements permit one failure per lot.

Samples of the M42/M46 loaded extruded grenade body assemblies were delivered to ARDC for the fragmentation and lethality tests. Standard M42/M46 grenades and previous historical data were used as the control to determine comparability to the current grenade.

The results of the fragmentation tests were encouraging. The average fragment weight for each of the three extruded M42 grenades varied from the standard by -5% to +17%. The number of fragments varied from +1% to -9% for the three samples. The extruded M46 data had a spread of -12% to -4% for the average fragment weight while the number of fragments varied only 5%. The total weight of recovered fragments for all the grenades varied only 4% from the standard. Because of the impressive data collected from the fragmentation tests, the program was continued into the panel (lethality) tests.

Unlike the fragmentation tests, which provide data only on the mass breakup for the munition, the panel test generates data on fragment mass, density, and velocity distributions on a zonal basis. This information is used to determine the munition's effectiveness.

The lethality test results for the extruded M46 grenade were equal to or slightly more effective than the standard grenade against both standing and prone targets. The extruded M42 grenade was not as lethal as the standard grenade. The analysis of the test results indicated that the extruded M42 was 12% less effective against standing personnel and 22% less effective versus prone targets.

In order to account for the difference in lethality, an analysis of the fragmentation features (i.e., total weight frags, total no. frags, M, avg vel) was conducted. The total weights of fragments and average velocities of the extruded and standard grenade were comparable. However, the average fragment mass of the standard M42 is notably lower and it also emits nearly 30% more particles. The number of fragments is a major contributor towards effectiveness versus "soft" targets.

Another consideration affecting the lethality is the zonal region from which the fragments are rejected. Usually, particles from the mainspray zones of a weapon are the most effective. An examination of the data revealed that the standard M42 produces a higher concentration of mainspray fragments than the extruded grenade.

The knurl pattern (fig. 7) was empirically chosen based on the desired fragment weight and the availability of a standard angle wheel to provide that fragment size. It was recognized, at the time, that the fragment pattern chosen was only an approximation of the pattern in the standard grenade. There was not sufficient time or funds in this program to experiment with knurling patterns in order to obtain the optimum.

The ballistic tests were the final tests performed for this program. Forty-eight test projectiles were loaded with the extruded grenades. Projectiles 1 through 24 were inert and 25 through 48 were high explosive. The projectiles were environmentally conditioned in accordance with the requirements in figure 8 and inspected before firing.

Approximately 5% of the inert grenades that were recovered failed to pass a 1.52-inch ring gage. This was due to a very small ridge on the lip of the grenade. This condition is not unusual, and it has also been observed on the currently produced grenades. The submunition impact pattern on the field was consistent with that of the standard M483A1.

CONCLUSIONS

The test results indicate that the warm backward extrusion process is capable of producing an M46 grenade equal to or better than the currently produced M46 grenade in all respects at a cost saving of approximately $0.09 per grenade.

The extruded M42 is equal to or better than the current M42 in all respects except lethality. The extruded grenade is from 12% to 22% less lethal than the present grenade.

RECOMMENDATIONS

It is recommended that the Technical Data Package for the M46 grenade be modified to permit the use of bar stock as an alternative material. This would allow the M46 grenade to be manufactured by the warm backward extrusion process.

The extruded M42 should be developed further. The basic approach to extrusion appears sound, and further effort should be restricted to determining how to increase the lethality to the level of the present M42. Several different knurl patterns and fragment sizes should be investigated.

Table 1. Facility modifications

AVCO	Dayron	Tacor-MBA	Gulf & Western
Retool existing tansfer presses for cap forming	Retool existing transfer presses for cap forming	Add extrusion equipment	Add extrusion equipment
Use roll mill for cap embossing	Use roll mill for cap embossing	Add equipment to open cups, emboss and close cups	
Add assembly and weld operation	Add tube mill	Add assembly operations for cap, tube and copper ring	
Eliminate resize and restrike presses	Add assembly operations for cap, tube and copper ring	Add brazing furnace to heat-treat system	
Add cap push out test	Add brazing furnace to heat-treat system	Add cap push test	
	Eliminate resize and restrike operation		
	Add cap push out test		

Table 2. Test results, summary phase 1

Test	AVCO	Dayron	Tracor-MBA
Hardness (Rockwell) M42, A 73 max M46, A 76 max	M42 $\bar{x}$ = 72.7 s = 0.95 M46 $\bar{x}$ = 72.1 s = 0.66	M42 $\bar{x}$ = 77.1 s = 0.55 (Did not deliver M46)	M42 $\bar{x}$ = 70.7 s = 0.78 M46 $\bar{x}$ = 75.1 s = 0.67
Cap push out (15,000 lb max)	Satisfactory	$\bar{x}$ = 9332 lb s = 1526 lb	M42 1@ 14,750 lb 1@ 12,600 lb M46 1@ 15,000 lb 1@ 11,800 lb
Stud pull test	$\bar{x}$ = 555 s = 149	$\bar{x}$ = 766 s = 63	Parts would not go in fixture
Transverse crush M42, 6,300 lb min M46, 7,500 lb min	M42 $\bar{x}$ = 9693 s = 332 $\bar{x}$ - 3s = 8697 M46 $\bar{x}$ = 10175 s = 318 $\bar{x}$ - 3s = 9222	M42 $\bar{x}$ = 7796 s = 307 $\bar{x}$ - 3s = 6875	M46 $\bar{x}$ = 7629 s = 558 $\bar{x}$ - 3s = 5955 M46 $\bar{x}$ = 8773 s = 653 $\bar{x}$ - 3s = 6814
Longitudinal crush M42, 65,000 lb min M46, 85,000 lb min	M42 $\bar{x}$ = 92275 s = 752 $\bar{x}$ - 3s = 90019 M46 $\bar{x}$ = 86750 s = 1585 $\bar{x}$ - 3s = 81994	M42 $\bar{x}$ = 90526 s = 2144 $\bar{x}$ - 3s = 84094	M42 $\bar{x}$ = 85412 s = 1787 $\bar{x}$ - 3s = 80052 M46 $\bar{x}$ = 95342 s = 2192 $\bar{x}$ - 3s = 88766

Table 3. Comparison of contractor processes

	Advantages	
AVCO	**Dayron**	**Tracor-MBA**
Relatively simple process	Undistorted pattern (same process)	Material savings in bar stock
	Possible elimination of M46	

	Disadvantages	
AVCO	**Dayron**	**Tracor-MBA**
Two-piece design	Two-piece design	Two-piece design
Higher priced tubing	Tube mill required	Copper braze
Tubing dimensional control	Tubing strength	Emboss pattern uniformity
Laser weld spatter and voids	Copper Brazing	Opening and closing of M42
Knurling fragmentation pattern		Retrofitting existing facilities
Knurl tool life		

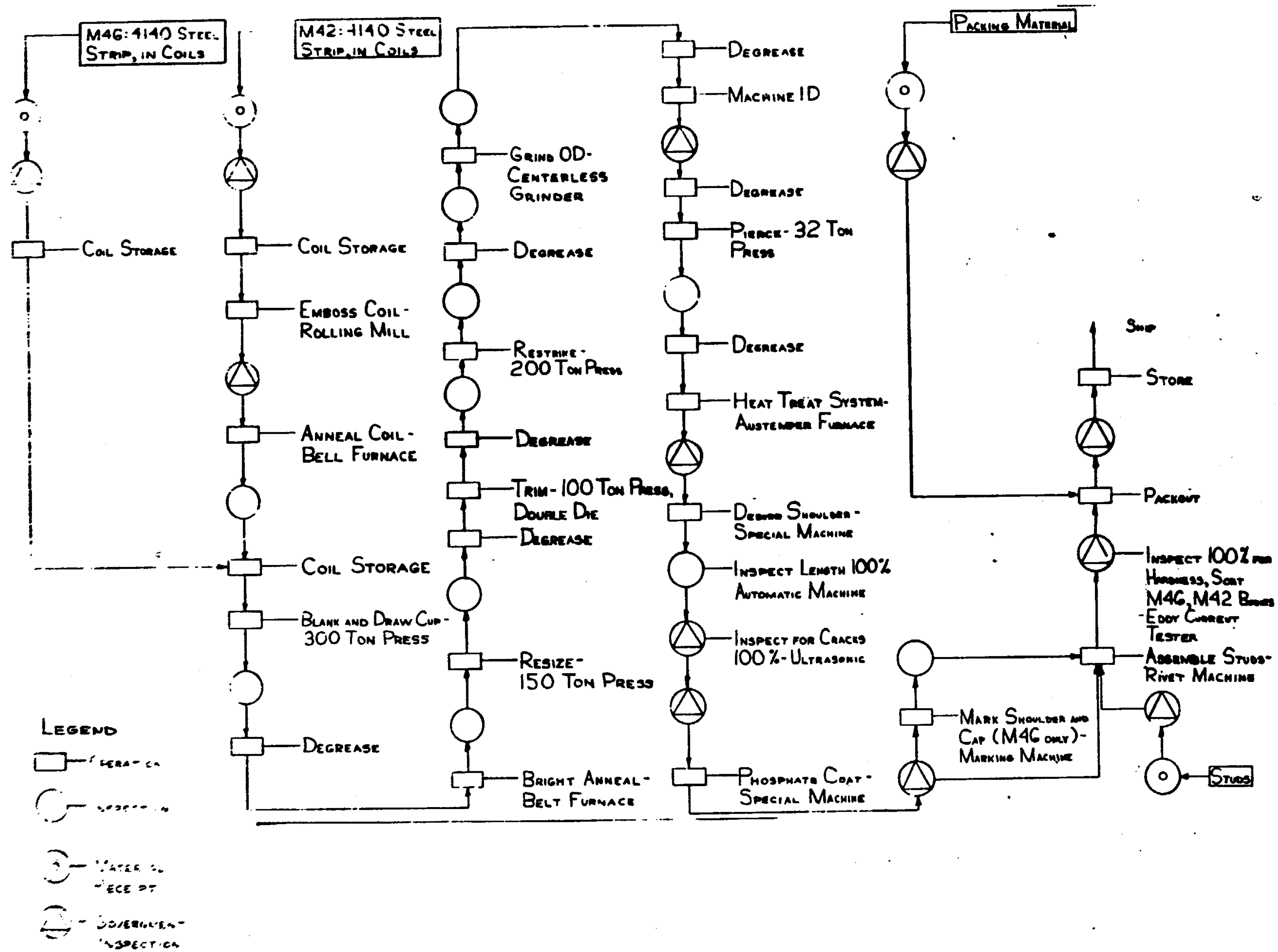
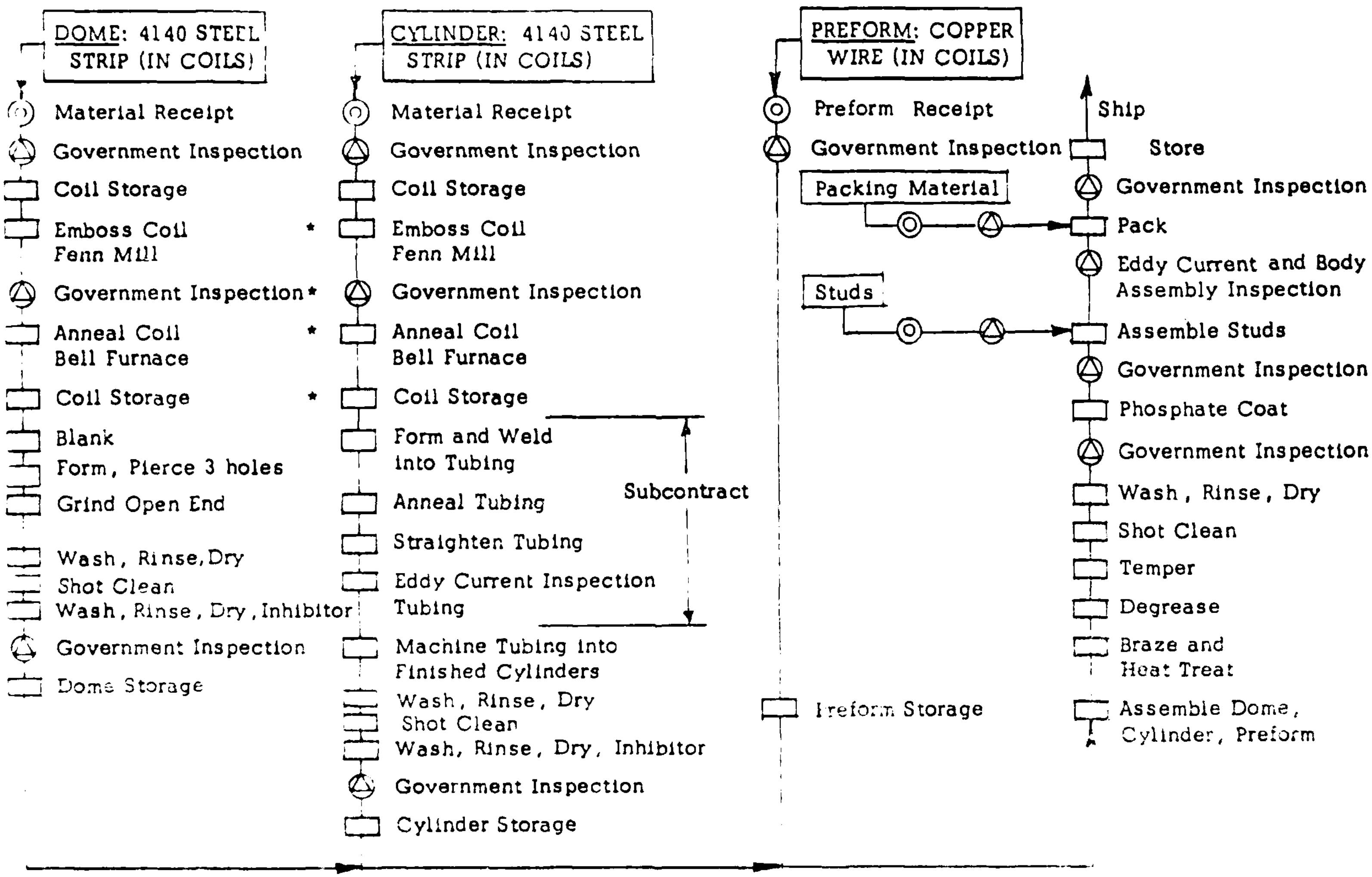


Figure 1. Original process flow chart



* Operations not required for M46 Grenade Body Assembly

Figure 1. Dayron process flow chart

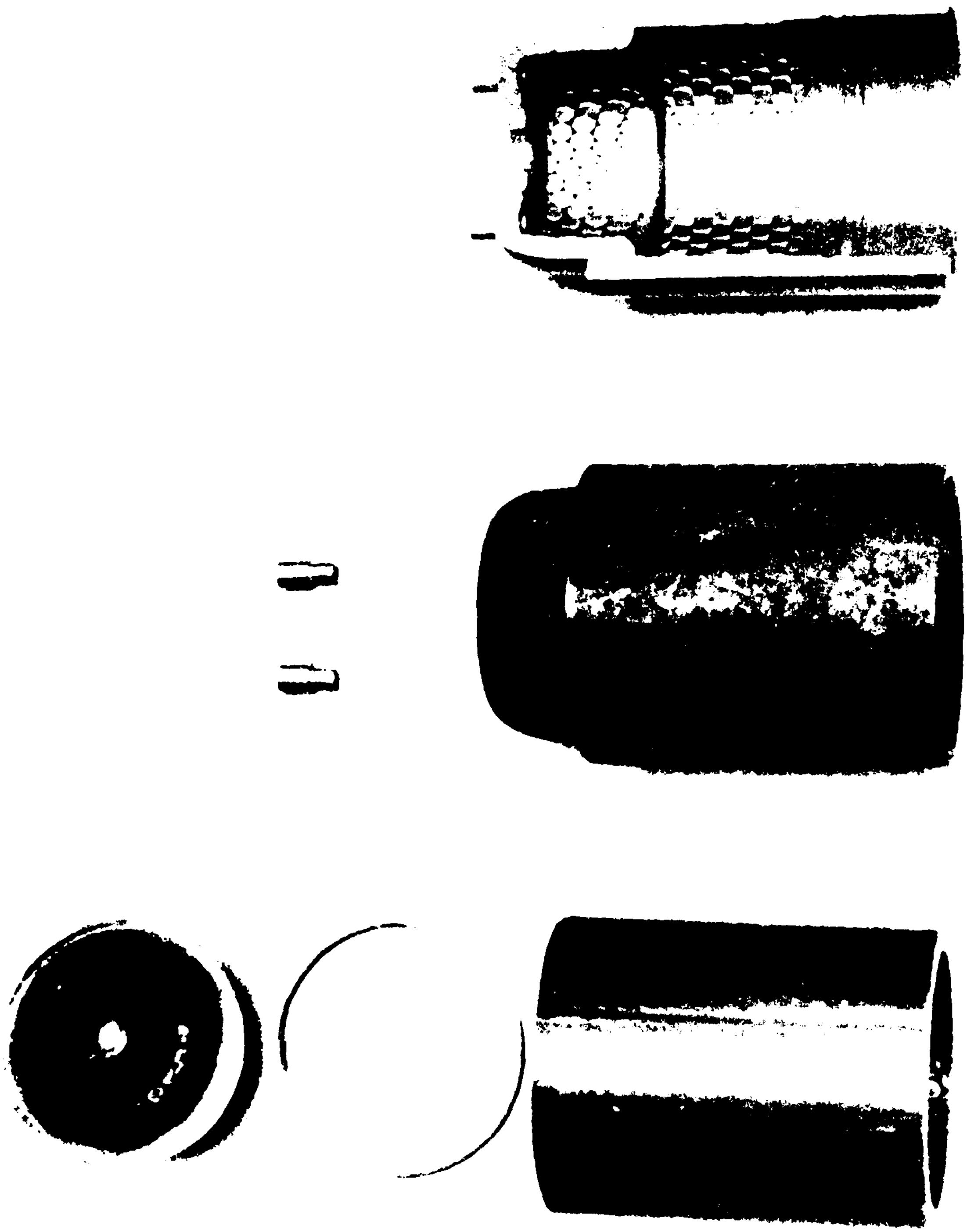


Figure 3. M42 brazed body assembly and components

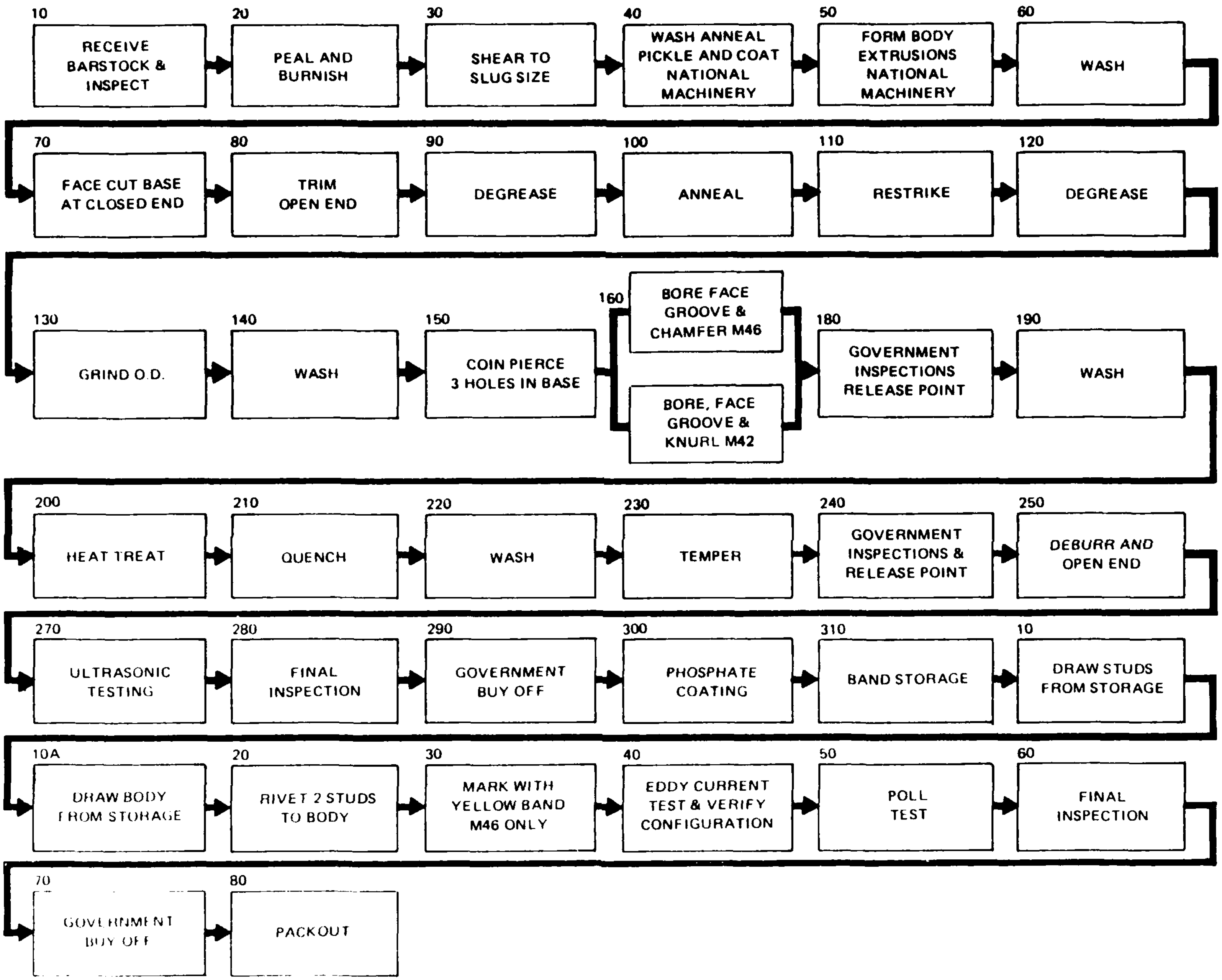


Figure 4. Tracor-MBA process flow chart

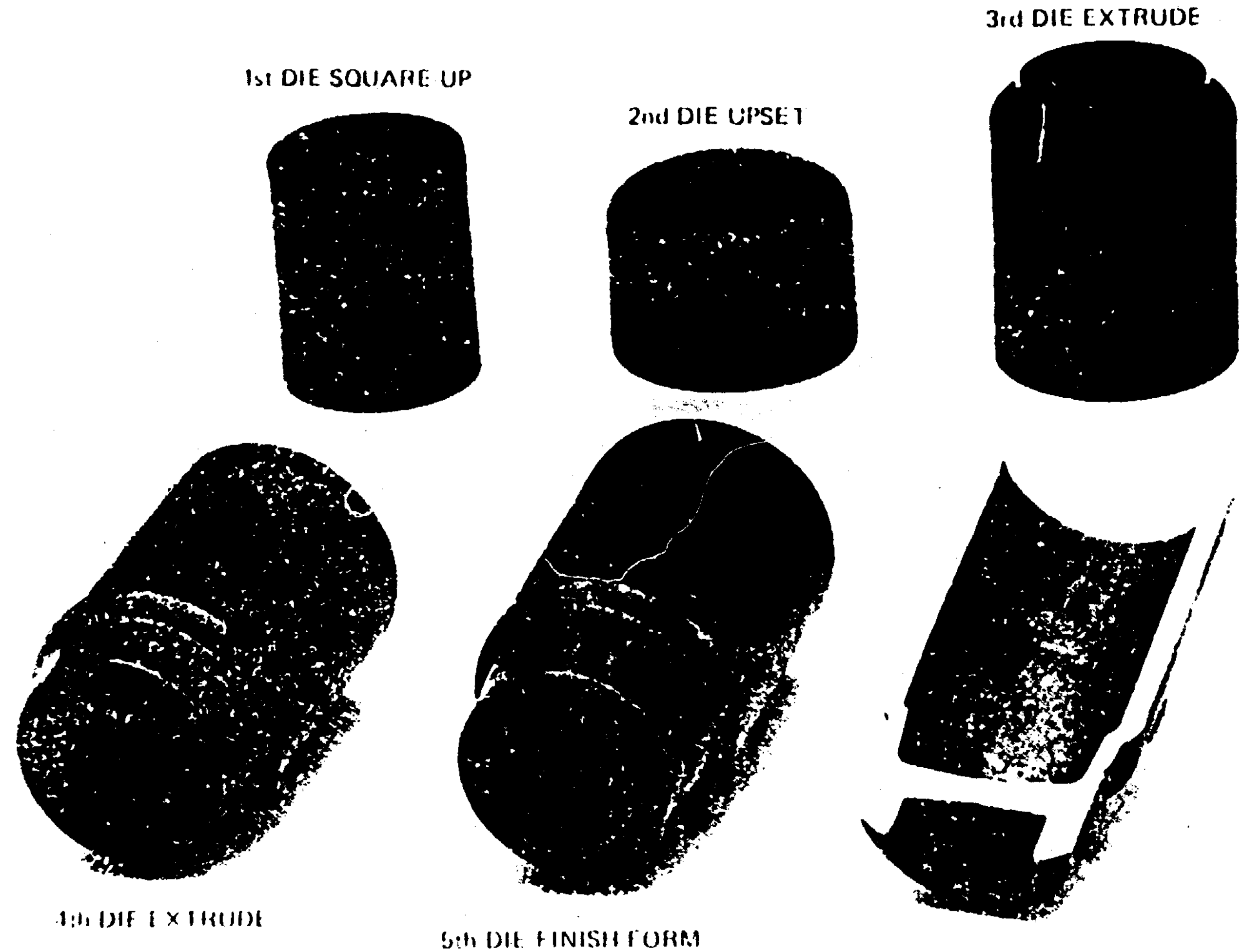


Figure 5. Extrusion station configurations

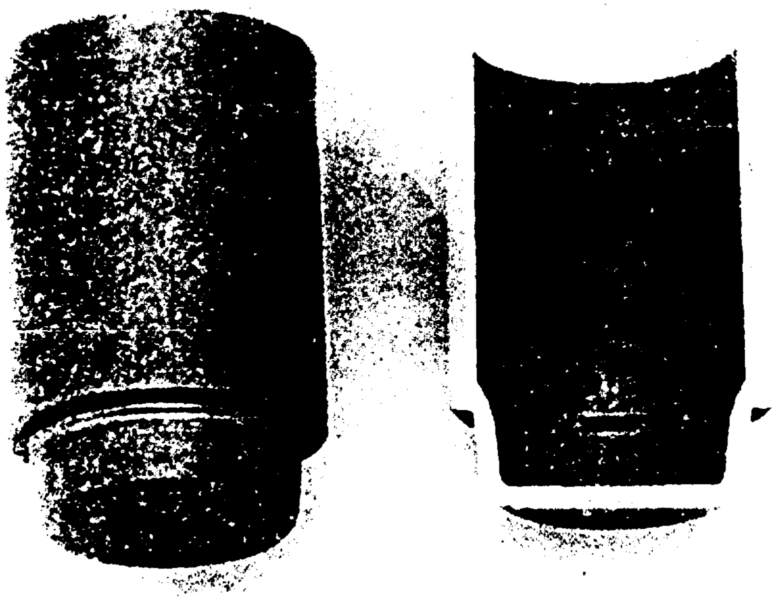


Figure 6. Extrusion body restrike

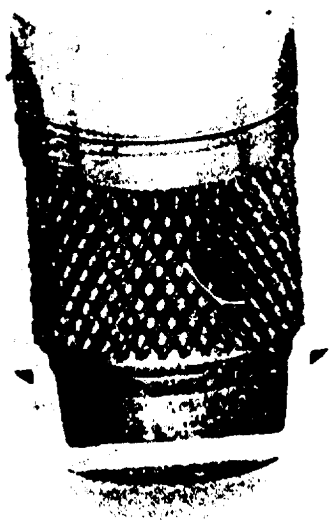


Figure 7. Kn'ırled M42 extruded body

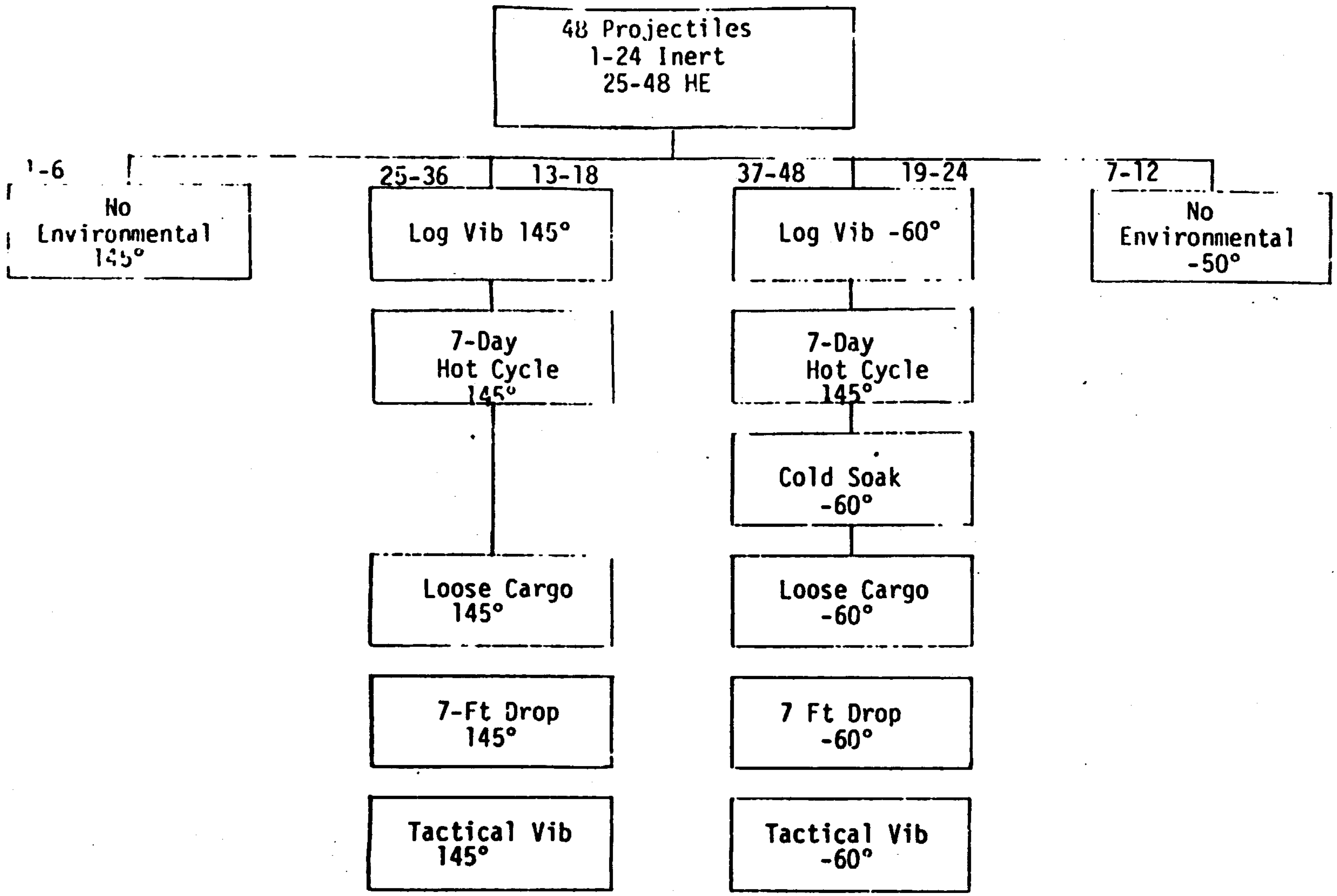


Figure 8. Environmental conditioning

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